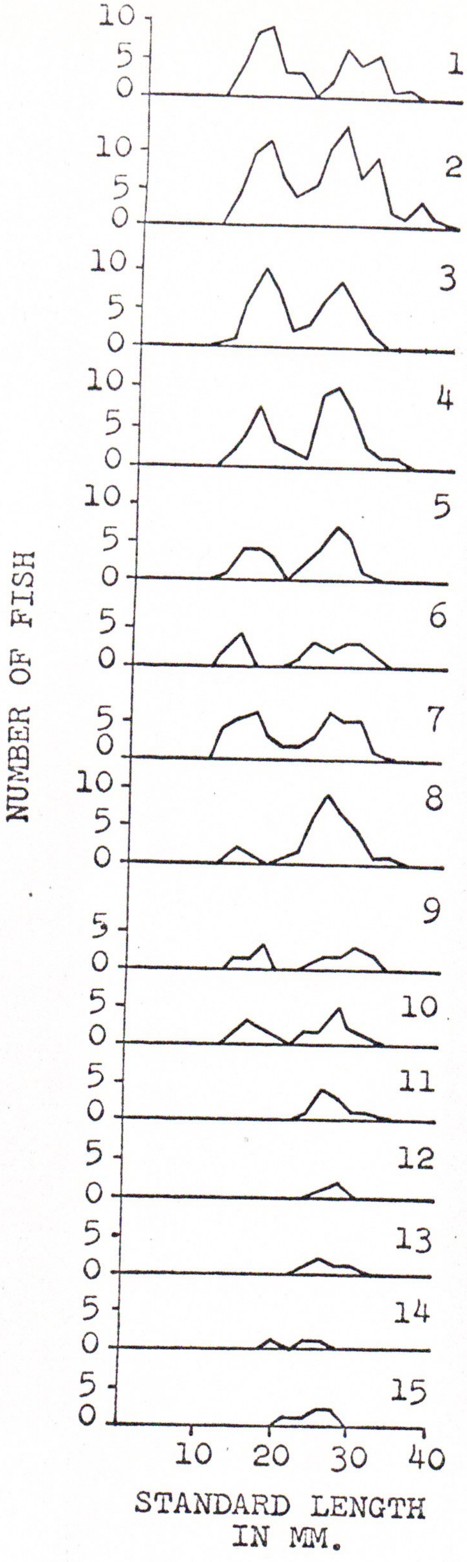

Figure 35. Length frequency relationships of fish captured from experimental coral heads at Waikiki in 1961.

fish captured from the experimental coral heads at Waikiki on July 30. Fish lengths were grouped by 2 millimeter intervals to produce the curves. The data show 2 distinct modal distributions which probably represent the influxes of fish noted in Figure 34. The peak formed by the larger fish probably represents those that appeared about June 22, but which had increased in length by the time of capture. The other peak probably represents the influx of juveniles that occurred between July 5 and 30.

3.12.2 Experiments at Waimanalo

Pocillopora meandrina coral heads were secured from nearby areas and were transported to the study areas, where they were affixed to the bottom as already noted. Fish were captured on other sections of the reef and were transported in nets to the study area without having left the water.

Four coral heads were randomly placed in section B over the rock bottom and four were similarly placed in section D over the sand bottom (Figure 16). Five fish were released into each head on June 19, 1961, and each head was watched to make sure that the fish entered and remained therein. In all cases, fish were responding normally shortly after release.

Figure 36 shows that numbers of fish tended to increase on the sandy section at Waimanalo, whereas they decreased on the hard bottom. Thus, the results are similar to those at

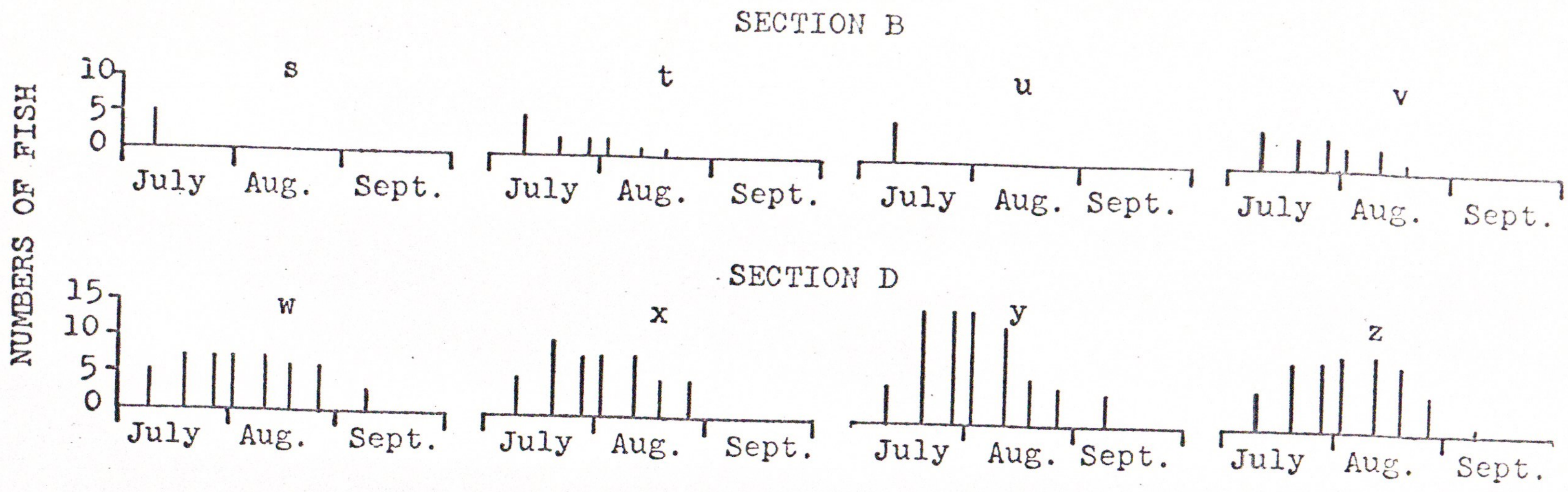

Figure 36. Observations of numbers of fish colonizing experimental coral heads at Waimanalo in the summer of 1961.

Waikiki, although the aggregations did not become so large. It is important to emphasize the fact that the aggregations introduced on the rock bottom of section B, where there was a great amount of surge, did not maintain their numbers whereas those on the rock bottom section of Waikiki where the water was very calm did maintain their abundance. This again shows that surge plays an important part in determining the distribution of juveniles.

The experimental data confirm the observations made on fish under natural conditions, i.e., juvenile *Dascyllus albisella* build up large aggregations in coral heads in calm water over sand. However, heads associated with hard bottom (in both a shallow, surge-prone section as well as a calm, deep section) contains very few fish. As will be seen in the section on predation (Section 3.16), the scarcity of aggregations on the hard bottom in the calm, deep section of Waikiki is thought to result more from predation than surge, although the latter is doubtless important in the shallow section at Waimanalo.

3.13 ASSOCIATION WITH SEA URCHINS

Young *Dascyllus albisella* were first observed living among the spines of the poisonous sea urchin, *Echinothrix diadema*, along the sea wall at Honolulu Harbor in July of 1959. One urchin had a population of three fish and the other, five fish. One other similar observation was made in deep water off Waikiki in 1959 in which the urchin had an associated aggregation of 16 fish. It was not possible to catch any of these fish, but it was recognized that all of them were of a very small size.

On June 11, 1961, considerable numbers of juvenile *Dascyllus albisella* were observed associating with *Echinothrix* in section A of the Waikiki study area. From this time until the study was terminated, urchins were kept under observation and counts were made to determine the magnitude of the fluctuations in numbers of associated fish.

Table 12 shows the results of observations made of the numbers of juvenile fish in relation to numbers of urchins. From both the total numbers of fish found in the urchins and the percentages of inhabited urchins between June 11 and July 30, it appears that there were three influxes of juveniles. One of these occurred on or prior to June 11, another between June 15 and 22, and another between July 5 and 30.

The data indicate a cyclic influx of juveniles during which the fish temporarily inhabited the spines of the sea urchins. Two of the periods during which considerable numbers of fish occupied the urchins were shortly followed by periods when few or no fish could be found. This sudden

Nos. juvenile D. alb. colonizing sea urchins (E. diad.)

TABLE 12. RELATIONSHIP BETWEEN NUMBERS OF SEA URCHINS (*ECHINOTHRIX DIADEMA*) AND NUMBERS OF JUVENILE *DASCYLLUS ALBISELLA* ASSOCIATED WITH THEM DURING SUMMER OF 1961.

Collection Date	Total No. Urchins	Total No. Fish	No. Urchins Inhabited	% Urchins Inhabited
June 11	80	58	14	17
June 15	108	7	5	3
June 22	89	81	23	26
June 23	77	75	20	26
June 25	75	5	3	4
July 5	73	0	0	0
July 30	87	39	18	21

disappearance resembles that which occurred in coral heads at Waimanalo in both 1960 and 1961, and supports the idea that juvenile fish may set up a temporary association with either coral heads or urchins (and perhaps other objects) before moving to other locations.

3.14 ASSOCIATION WITH ANEMONES

Commensal associations between pomacentrid fishes of the genus Amphiprion and large anemones of a number of genera have received considerable attention since they were reported by Collingwood (1868). Details of the behavior of these fishes toward their carnivorous host and aspects of their life histories have been reported by Verwey (1930), Gohar (1948), Abel (1960) and Eibl-Eibesfeldt (1960). Gudger (1947) has reviewed the literature up to that time.

The acclimation process whereby the fish is enabled to swim freely among the tentacles of the anemone without being seized and devoured is of the utmost importance to the survival of the animal. Davenport and Norris (1958) gave physiological evidence that a factor in the skin of Amphiprion percula raised the threshold for nematocyst discharge, thus blocking the stimulus necessary to induce the anemone to seize the fish. They also described in detail the behavior of the fish that resulted in the production of the necessary protective factor. However, the possible origin of the behavior pattern has not been explained.

Although juvenile *Dascyllus trimaculatus* have been reported to remain in the vicinity of large anemones (Harry, 1953; Eibl-Eibesfeldt, 1960), it has not been reported hitherto that juvenile *Dascyllus albisella* are sometimes found as a commensal with the small anemone, *Marcanthia cookei*. Unlike *Dascyllus trimaculatus* which flees beneath the oral plate but does not touch the tentacles, *Dascyllus albisella* takes refuge among the tentacles of its temporary anemone host. Although this species belongs to a different genus from the generally recognized anemone fishes, and although the anemone is much smaller and belongs to a different genus than those associated with anemone fishes, the acclimation process is similar. Observations of the behavior of this species not only toward its anemone host but also toward corals and other objects has suggested a possible origin of sea anemone commensalism which will be discussed below.

Studies of the behavior pattern of juvenile *Dascyllus albisella* toward both coral and anemones were conducted primarily in aquaria. Field observations of fish and anemones showed agreement with those made in aquaria. The fish that were observed varied in length from 15 to 18 mm. The anemones varied in width from 100 to 125 mm. The sizes of both fish and anemones approximated those observed in the field.

When first introduced to an anemone, juvenile *Dascyllus albisella* show the same type of behavior as reported for *Amphiprion percula* by Davenport and Norris (1958). Fish approach the anemone and usually swim around and over it for a short time before contacting the tentacles. They sometimes settle down near the stoma for a few seconds and then continue their "investigation". Unlike *Amphiprion percula* which touches the anemone with the lower margin of the caudal fin or the ventral edge of the anal fin while swimming over the disc, *Dascyllus albisella* usually comes to a halt at the side or over the top of the anemone and backs into the tentacles. Actual contact with the anemone takes place along the posterior or anal edges of the caudal fin or anywhere along the anal fin. The anemone usually adheres to the fin at which the fish violently jerks loose and turns to face the anemone. This latter activity is thought to have important significance in the evolution of the behavior of anemone fishes and will be discussed later. The anemone does not always adhere to a fish at every contact, which may indicate either that different areas of the fish cause different responses or that the tentacles may respond differently at different loci along their length. The fish may either wander away from the anemone for a few minutes, or it may remain close to it and continue to make contact. Occasionally fish approach the anemone headfirst and nip the tentacles. Judging from the vigorousness of the action, this is apparently not a response to food particles. Similar activity is well known among anemone fishes which actually feed on the tentacles.

The initial contact is usually as described above, but occasionally the fish first contacts the anemone with its body. However, this type of behavior usually occurs later in the acclimation process when the fish may bend its body while backing into the anemone, or when it settles down on the disc and leans against one or more tentacles which usually do not adhere to the fish.

As acclimation proceeds, the fish back deeper among the tentacles and lie on the sides but the tentacles seldom adhere to them. At this time all motor activity, except respiration, usually ceases for periods up to 30 seconds or more after which the fish right themselves and remain finning in one spot or else move over the anemone again or away from it. Such cessation of motor activity is unusual among fishes and is shown by Dascyllus albisella only after contact with the anemone or during "sleep" when the fish lean against the branches within coral heads. This behavior is different from that of Amphiprion percula which at this time during the acclimation process dashes back and forth across the disc among the tentacles (Davenport and Norris, 1958).

Dascyllus albisella do not remain close to the anemone for very long periods in the aquarium, but spend most of their time swimming elsewhere. Verwey (1930) noted similar behavior in *Amphiprion percula* that had become tame in the Onrust Aquarium in Batavia. When acclimated *Dascyllus albisella* return to an anemone after having spent 5 or 10 minutes away from it, they back into the tentacles without hesitation and sometimes remain the the vicinity nipping them or touching them with the caudal fin. In the field, they may take refuge among the tentacles, or may hide instead among rocks adjacent to the anemone. It would seem from these observations that the anemone might not offer the fish as much of a "feeling" of security as some other objects such as coral heads.

Whether or not the tentacles of the host react to the presence of the fish has been the subject of discussion by a number of authors. Crespigny (1869) and Herre (1936) both reported that the tentacles of the host moved apart in response to the presence of acclimated fish. However, Davenport and Norris (1958) could detect no such movements and suggested that those witnessed by Crespigny and Herre were the result of water movements. The tentacles of *Marcanthia cookei* showed a definite reaction to *Dascyllus albisella* both in the laboratory and in the field. Fish that lay quietly among the tentacles were often rocked back and forth by the action of the tentacles, which actively curled around them. At other times when fish were immobile or finning quietly in one spot, individual tentacles were seen to curl around and seemingly touch the fish with their tips and then quickly withdraw by both contracting and swinging away. The action strongly suggested contact by the tentacles with an agent that definitely repelled them. Whether or not the "agent" was chemical in nature or whether the tentacles were showing a thigmotactic response in not known.

The degree of commensalism existing between Dascyllus albisella and Marcanthia cookei appears to be much less intimate than between Amphiprion sp. and the larger anemones they usually inhabit. Sluiter (1888) and Verwey (1930) observed that anemone fishes in aquaria picked up pieces of food that had been thrown in and deposited them on the tentacles of the anemone, which thus benefited by receiving food not normally available. Gohar (1934) asserted that Amphiprion bicinctus in the Red Sea hunted food and "dragged" living fish almost their own size to the anemone which devoured them. He also observed that fish cleaned out the gastrointestinal cavity of the host.

The anemone fishes benefited from the protection afforded them by the tentacles and numerous observations conrmed that they not only ate the tentacles, but also picked from them organisms that had been caught by the anemone.

It is doubtful whether fish as timorous as small juvenile *Dascyllus albisella* that feeds on plankton would bring food to the anemone and judging by their small size while inhabiting anemones (15 - 18 mm.), they would not be large enough to feed on the tentacles. Care of the anemone by "preening" the tentacles was never observed. Incidental fanning of the anemone by the fish, which some authors interpret as functioning to bring a fresh oxygen supply to the anemone or to remove waste products, would be of doubtful benefit to *Marcanthia* which lives close to the surface on reef flats that are almost continually washed by small waves.

It is apparent that the behavior of *Dascyllus albisella* toward an anemone is unusual when it is compared with the behavior displayed toward coral heads which are more frequently inhabited. When first exposed to a coral head, juvenile *Dascyllus albisella* either swim slowly over its surface or immediately enter the interstices and swim slowly around. Within a few minutes the swimming speed increases and they dash around among the interstices occasionally stopping to face outward, after which they continue their high rate of activity. This may continue for five minutes after which they swim more slowly and leave the confines of the coral head to begin feeding outside it. "Tail-touching" may occur after the fish are fairly well acquainted with the coral head. It was observed only in rare instances, and was seldom repeated as with anemones. Fish occasionally pick vigorously at the coral branches, but the cessation of motor activity that occurs with anemones was never seen.

It might be briefly mentioned here that juvenile fish associated with the long-spined urchin, Echinothrix diadema, in an aquarium often displayed a characteristic fluttering of the caudal fin that is associated with "tail-touching". It is thought that this activity might be released by the sign stimulus presented by relatively sharp-pointed objects such as sea urchin spines and Marcanthia tentacles.

3.14.1 Origin of Commensal Association

The development of commensal associations between animals is based on changes that occur in one or both of the partners. Such changes result from the interactions between the animals and also from the influence of environmental factors such as the type of available shelter, the presence of other animals, etc. In addition, one or both of the partners may have had certain behavioral, physical or physiological characteristics that would make them partially suited for a mutual existence. The following discussion points out some of these characteristics.

Fishes of the family Pomacentridae, as well as other fishes, are strongly influenced by their immediate surroundings. Although the adults of some species of the genera *Chromis*, *Dascyllus* and *Abudefduf* feed at a considerable distance above the bottom, most species remain in close contact with some kind of bottom cover. All of the species that have been observed to spawn have laid their eggs on the bottom in places which they have first prepared by fanning away or picking off loose materials. Many species develop commensal associations with other organisms. At Eniwetok Atoll, juvenile *Dascyllus reticulatus* are most often found living with the coral species *Acropora nasuta* and *Pocillopora eydouxi* or forms that appear much like these (personal observation). In the same area, juvenile *Dascyllus aruanus* are most often found with *Acropora echinata* and *Acropora nasuta*, whereas adults become associated with the staghorn coral, *Acropora accuminata*. Franzisket (1959) who worked in the Indian Ocean, showed a photograph of juvenile *Dascyllus aruanus* with *Acropora echinata* or a similar form of coral. Cott (1940) related the disruptive coloration of this fish with staghorn coral which is generally referred to by other authors as the habitat of this fish. However, Smith (1960) observed that *Dascyllus aruanus* was usually associated with weeds in shallow water; this is doubtless an unusual response to local conditions. In Hawaii, juvenile *Dascyllus albisella* is most often found with either *Pocillopora ligulata* or *Pocillopora meandrina* and occasionally with the less common anemone, *Marcanthia* cookei, and with the long-spined urchin, Echinothrix diadema.

In addition to forming commensal associations, pomacentrids show other intimate relationships with their surroundings. Limbaugh (ms.) observed the reproductive activity of the garibaldi, Hypsypops rubicunda, which makes its nest by cleaning off the surface of rocks, but "cultivates an elliptical patch of velvety red algae" on which the eggs are eventually placed. Pomacentrus leucostictus commonly lays its eggs in old conch shells (Brinley 1939) and Breder and Coates (1933) observed that a pair of breeding adults carried mouthfuls of sand which they blew at the nesting site apparently scouring the surface. Breder (1949) observed that Pomacentrus leucostictus, which had become acclimated to an aquarium, carried away stones that were placed near an aerator which the fish frequented. Verwey (1930) observed a specimen of Premnas biaculeatus in the Onrust Aquarium in Batavia which "deepened out a hole under its anemone by loosening pieces of coral shingle of the tank bottom with its mouth, removing them to a small distance and depositing them there". The latter author also observed that Amphiprion polymnus, Premnas biaculeatus and Amphiprion ephippium carry food particles to their anemones but with varying degrees of development of this trait among the species.

It is apparent from these observations that fishes of this family react toward objects in their environment both by congregating within or near them and by making physical contact with them. Many hours of observing Dascyllus albisella have shown that they have great curiosity toward objects that are placed in the aquarium with them. They slowly approach a foreign object and appear to inspect it from a distance which shortens until they have reached the object. At this time they almost always turn and "fan" the object with the caudal fin and many times appear to touch it. Only occasionally do they rapidly dart a short distance away and turn to inspect the object as do fish in the presence of an anemone. Their curiosity is usually quickly satisfied and they leave the object. The "tail fanning" behavior is displayed not only toward inanimate objects such as stones, aerator tubes, etc. but is also directed toward other fish, either of the same or different species. When directed toward other fish "tail fanning" may serve as a form of fighting behavior. During such activity, the caudal fin may be directed toward the head end of an opponent or the fish may assume a position almost parallel to the other fish and slowly approach it sideways while fanning. Breder (1950) observed that Pomacentrus leucostictus engaged in such activities by fanning away sand from the nest as well as "invertebrate marauders".

The motions used by adult fishes in fanning the nest serve to remove foreign particles as well as to aerate the eggs (Helfrich, 1958; Shaw, 1955). Nest "fanning", however, appears to employ a more vigorous use of the main body musculature than the "fanning" of miscellaneous objects. The body motion of fish engaged in nuptial display is more accentuated than the body motion of fish that are "fanning" eggs, but is less vigorous or absent in fish that are merely "fanning" various objects with the caudal fin. It appears that *Dascyllus albisella* are prone to display a particular type of motor activity when engaged in various kinds of behavioral activity, and it is expected that the particular type that has developed in relation to "tail-first" investigations of strange objects may have been instrumental in developing relationships between pomacentrids and anemones.

The release of the tail-fanning and tail-touching response by sign stimuli from all kinds of objects, along with the natural curiosity of the fish toward objects in its environment, is a possible basis for the origin of the commensal behavior of pomacentrids with anemones. The adhesion by the tentacles of the anemone to the edges of the caudal or anal fins of "curious" fish that were inspecting them could have great significance in the formation of the association. Since the tentacles stick to such edges, the fish has to jerk itself loose much as *Dascyllus* and *Amphiprion* do early in the acclimation process. Whereas touching most objects evokes no response from juvenile *Dascyllus*, the momentary adhesion of the tentacles acts as a stimulant. After jerking loose, they immediately turn around to face the anemone and after a short period of time begin to approach it again. It is conceivable that a number of such experiences might have induced certain fish to remain in the vicinity of anemones until behavior patterns and physiological processes associated with the anemone were evolved.

3.15 ASSOCIATION WITH OTHER CORALS AND ANIMALS

Young _Dascyllus_ have been observed associating with coral of the genus _Porites_. However, the frequency of such associations is low compared with the number of _Pocillopora_ heads that are colonized. The heads involved in such associations are almost always found under conditions similar to those surrounding _Pocillopora_ heads. _Porites_ heads often grow close to each other and tend to form clumps that may extend over many square yards. However, those with associated fish have always been individual heads growing at least two or more feet from others of the species. In addition, they have always been located in deeper waters where the surge is reduced. Such associations have been observed on a number of occasions in the entrance channel to the Coconut Island Marine Laboratory, on flats about 200 yards inshore of the study area. Associations with _Porites_ _pukoensis_ have been mentioned in connection with section 3.2.

Small aggregations were occasionally found at Ala Moana Beach Park living within clumps of the bivalve mollusc Ostrea sandvicensis. The fish were hard to catch in such places and they did not seem to persist there for long periods of time. Since Ala Moana is a popular collecting area, it is not known whether the aggregations disappeared from natural causes or whether they were caught by people.

Occasionally, clusters of calcareous tubes of annelid worms (Serpulidae) attached to pilings in Honolulu Harbor were found to have associated aggregations of juvenile Dascyllus albisella ranging in size from 15 to 25 mm. The tubes were mostly in the intertidal zone and the fish remained close to them at all times, rising and falling with the tides. As many as 80 to 90 fish have been observed congregating around a few clusters of tubes which apparently afford good protection. The tubes, which were up to 3 inches in length, clustered closely together and somewhat resembled a coral head in appearance. It might also be mentioned that no predatory species of fish were seen in the vicinity of the worm tubes.

3.16 PREDATION

The nature and extent of predation of juvenile Dascyllus albisella is difficult to evaluate. Since juveniles are normally only a short distance away from the protective confines of a coral head, it is likely that it would be difficult for a free swimming predator to catch them. Potential predators are difficult to catch for stomach analysis. Moreover, Dascyllus albisella are relatively scarce compared with other potential prey such as anchovies and silversides, thus decreasing the probability of finding them among the stomach contents of predators. The available information on this question is based on observations in the field.

3.16.1 Invertebrate Predators

Of the invertebrate animals observed only the mantis shrimp was seen to display any interest in juvenile Dascyllus albisella. This animal is well equipped for the role of predator since it has large raptorial chelipeds for grasping as well as the ability to move quickly. Mantis shrimps were seen to catch juvenile fish on two separate occasions, although the conditions under which they occurred were not wholly natural. On one occasion, a juvenile fish that had recently been released was seized by a two-inch shrimp as it struggled close to the bottom near the coral head in which it had been released. The fish was in an obvious state of physiological stress, and was not behaving normally. On the second occasion, a young fish was seized by a shrimp about 2½ inches in length as it swam close over the surface of a coral head. The fish was one of a group of 6 individuals that had retreated close to the head apparently in response to the presence of the observer. On another occasion, a mantis shrimp was seen attempting to catch a young fish that had recently been released. The fish was apparently under no stress, and was swimming around about 4 inches from a coral head. The shrimp was seen to dash out from the head and to strike at the fish which eluded it.

These observations are not presented as proof that the mantis shrimps are normal predators on juvenile _Dascyllus albisella_. However, some species are normal inhabitants of coral heads and the fact that they are able to catch fish under certain conditions indicates that they might sometimes prey on them.

3.16.2 Vertebrate Predators

During the course of the studies, it was noticed that many coral heads were inhabited by small fishes of the family Scorpaenidae. Because of the predatory habits of fishes of this family as well as their favorable location in relation to juvenile _Dascyllus albisella_, they were suspected of feeding on them. Therefore, 15 of these fishes were captured and identified as to species -- _Scorpaena ballieui_ (11 specimens) and _Scorpaena coniorta_ (4 specimens). The captures were made from areas near Waimanalo during the course of other work.

Neither the stomachs nor the intestines of these fish contained recognizable remains of Dascyllus albisella. However, comparing the number of stomachs containing food with the number of intestines containing material in a later stage of digestion, it would seem that the fish fed some hours before capture. Since many fishes of this family are nocturnal feeders and since most of the fish contained food in an advanced stage of decomposition, it is reasonable to assume that they might feed at night. This raises the possibility that they might prey on juvenile fish at night when they return to the coral head. More information might be gained on the particular question by making collections very early in the morning. Although some Dascyllus albisella in aquaria "sleep" within coral heads at night, others do not. Although observations were not made at night in the field, it is probable that juvenile fish remain close to or within coral heads during the night.

In 1960, observations were made of the number of scorpaenids that were seen in coral heads in sections A and B at Waimanalo and also on the number of Dascyllus albisella inhabiting the heads at intervals over a two-week period. These data are presented in Table 13. It is apparent that large fluctuations in numbers of fish took place in heads 1, 2 and 3 of section A and in head 1 of section B in the absence of scorpaenids. The decrease in numbers between July 20 and 22 could well have been due to some factor other than predation since it occurred in a number of heads at the

	SECTION A										SECTION B									
	JULY										JULY									
HEAD NO.	16	17	18	19	20	22	23	24	27	30	16	17	18	19	20	22	23	24	27	30
1	7/0	9/0	10/0	12/0	20/0	8/0	4/0	6/0	5/0	5/0	6/0	6/0	8/0	14/0	13/0	8/0	5/0	5/0	4/0	3/0
2	2/0	4/0	5/0	5/0	9/0	8/0	9/0	10/0	9/0	6/0	1/1	2/1	?	2/1	7/1	2/1	2/1	3/1	1/1	0/1
3	9/0	7/0	7/0	10/0	23/0	16/0	18/0	16/0	12/0	7/0			1/0	3/0	3/0	1/0	1/0			
4	5/1	8/0	6/1	7/1	25/0	24/1	12/1	12/0	5/0	3/0	6/1	5/1	6/1	11/1	15/1	7/1	4/2	5/3	4/1	2/1
5		1/3		2/2				1/1					2/1	3/1	4/1	1/0	1/0	1/0		
6	1/0	1/0	1/0	1/0	2/1	2/1	3/1	1/0	0/1	0/2					2/1	1/1	1/1	1/1	1/1	
7	2/1	2/1	1/1	1/1	3/1	2/1	1/1	1/1						3/0	3/0	1/0	1/0			
8	1/0	2/0	2/0	3/0	1/0	5/0	2/0	3/0			3/0	4/1	7/1	16/1	24/1	6/0	8/0	5/0	4/0	2/0
9	no data										no data									
10				5/0	5/2	8/2	12/0	16/0	10/2	8/2			3/0	2/0	1/0	1/0	1/0			
11	no data												3/2	3/2	3/2	4/2	4/2	3/2	2/2	2/2
12						2/0	2/0								2/0					
13													2/0	2/0		1/0				

TABLE 13. NUMBERS OF JUVENILE DASCYLLUS ALBISELLA (NUMERATOR) IN RELATION TO NUMBERS OF SCORPAENID FISHES (DENOMINATOR) ASSOCIATED WITH THE SAME CORAL HEADS AT WAIMANALO DURING THE SUMMER OF 1960.

same time (section 3.2.1). The decrease also occurred in other heads that had associated scorpaenids. The fact that scorpaenids were not observed in coral heads in which numbers of fish decreased does not imply that predation did not take place, since scorpaenids might visit different heads at night. However, it does imply that relatively large decreases in numbers of fish can take place in heads that are not populated by these predators. What appear to be the same scorpaenids can be repeatedly seen in the same head and often in the same spot, thus indicating that they remain in specific heads at least during daylight hours.

It can be seen from Table 13 that scorpaenids were not plentiful in either section. On any single day the most that were found were 5 individuals in section A and 7 in section B.

An indication that scorpaenids prey on Dascyllus albisella is suggested by the situation encountered at head #24a in section D at Waimanalo. This is not a single coral head, but a 4 x 7 foot mass of an arborescent form of Porites lobata. The patch when first discovered on May 29, 1961, had an associated aggregation of 25 juveniles, which gradually disappeared until none remained by June 30. When first seen, the juvenile Dascyllus albisella had singled out a conspicuous clump of coral that stood out among the general mass and the fish were feeding at this locus. A 5-inch scorpaenid fish of the genus *Dendrochirus* was also associated with the mass of coral. On three of the four subsequent observations of the *Dascyllus albisella* at this head, this scorpaenid (or one of similar proportions) was seen lying motionless at the base of the particular locus over which the fish were feeding. On each visit, the fish were feeding at a different locus, and the scorpaenid had changed its position accordingly so that it remained below the *Dascyllus*.

A number of other observations indicate that other species of scorpaenids prey on juvenile *Dascyllus albisella*. On two occasions in section A of Waikiki, large scorpaenids of the genus *Dendrochirus* were seen lying motionless at the bases of rocks where small juvenile *Dascyllus albisella* were living. The juveniles were feeding on a particular side of the rocks and the scorpaenids were lying directly beneath them. One of these fish, a 4-inch specimen of *Dendrochirus brachipterus* was captured, but its stomach was empty.

Three other species of predatory fish appeared to adopt a "stalking" attitude similar to that of the scorpaenids. On one occasion, a cornet fish (Fistulariidae) 2 feet in length, was seen floating motionless alongside experimental head #5 in section A at Waikiki. Although this head was in a sandy section, it was within 10 feet of the periphery of an area that was populated by coral heads and other fish. Several trumpet fishes (Aulostomidae) were seen hovering around experimental coral heads at Kewalo Basin where juvenile Dascyllus albisella had just been released. The absence of some of the juveniles strongly indicated that the trumpet fish had eaten them. On another occasion, a 12-inch lizard fish (Synodontidae) was seen lying beneath the same coral head. The final observation of apparent stalking was made about 40 yards to the southwest of head #5 where a 6-inch flounder (Pleuronectidae) was observed lying on the hard bottom facing head #10, and about one foot from it. The fish was initially seen as it approached the head from a distance.

With the exception of the scorpaenids, all of the predatory fish referred to above show essentially the same type of behavior in relation to the actual seizing of the prey. This consists of an extremely quick darting motion when the prey reaches a particular point in reference to the predator. The scorpaenids show a somewhat different behavior in this respect by typically waiting until the prey approaches to within a critical distance at which time they ingest it by creating a quick suction of water into the mouth. From the above observations, however, it appears that these species (and probably others as well) actively seek juvenile Dascyllus albisella and other species and lie in wait for them close to the coral heads in which they live.

It must be emphasized that the evidence to date is all circumstantial and Dascyllus albisella have never been identified from the stomachs of predatory fish.

3.16.3 Abundance of Predators

Since predators represent an integral part of the environment of juvenile Dascyllus albisella, some evaluation of their abundance and distribution is necessary to bring this factor into perspective in relation to surge. A great deal of experience in underwater observing over a number of years in the various types of marine environments has enabled a general analysis of this factor. Areas of considerable surge activity and areas of relatively quiet water each present rather well defined fauna that can be expected in such areas, providing the topographical features of the bottom and associated factors are the same.

Sections of relatively strong surge in the Kualua, Waimanalo, and Waikiki areas appeared to be devoid of the types of predators mentioned above, with the exception of Scorpaena ballieui and Scorpaena coniorta. Since none were seen during the normal course of observations, specific searches were made which included looking into crevices whenever possible. Predaceous fish still were not seen in spite of this extra effort. The coral heads in these sections did harbor the two species of small scorpaenid fishes mentioned above, but a comparison of their relative abundance between rough and calm areas was not made. It is doubtful whether the presence of these species alone could eliminate aggregations of juvenile Dascyllus albisella so quickly that they would seldom be seen in these areas.

The surge areas were rather devoid of small fish in general. The wrasses, chaetodonts, pomacentrids, apogonids, and other species that can almost always be seen in areas of quieter water were very scarce or nonexistent. It is probable that surge activity was also responsible for their absence. Whether or not the absence of predators is a reflection of the absence of prey species is difficult to say. It is probable that these species also cannot tolerate such hydrographic conditions. Most likely their absence results from a combination of these two factors.

The calmer areas can be divided into two types of habitats in relation to predator distribution. One of these types is typical of most of the Kaneohe Bay study area as well as sections C and D at Waimanalo and the sandy parts of section A at Waikiki. Such types of bottom are either sandy or are characterized by a flat, bare hard base of coral rock interspersed with patches of sand. Sand from the patches drifts into crevices in the harder parts of the bottom, thus filling up possible hiding places for bottom feeding predators. Predatory species have not been seen in such sections in Kaneohe Bay and with the exceptions noted earlier in this section, have not been seen near *Dascyllus albisella* in sandy patches of bottom. The exceptions are those discussed earlier in this section where a lizard fish and a cornet fish were seen lying beneath the same coral head at different times. Although the head in question was isolated on sand, the bottom around it that led to a nearby patch of coral was strewn sparsely with small rocks that probably afforded enough cover for the predatory fish to work their way to the head. The movement of the sand might be a more important factor than lack of cover in restricting the movements of relatively quiescent species of predators into such areas. The sand is often in motion to a greater or lesser degree and would tend to cover up a fish lying on the bottom. Possibly it would also interfere with the vision of the fish, which have no eyelids.

The second type of habitat involves calmer areas with rock bottoms such as those found in section A at Waikiki. Predatory species of fish in such areas are very numerous and include a number of different species of the types mentioned above. In addition, hawk fishes (Cirrhitidae) are very common and some species habitually "perch" on top of the few coral heads that were found in such areas. Other predators such as angler fishes (Antennaridae) and some wrasses (Labridae) are also present, but are less abundant. Although accurate counts were not made, it is conservatively estimated that at least 10 to 15 individuals of predatory species of fish were seen incidentally during each dive.

A more precise study of the distribution of juvenile Dascyllus albisella in relation to predator distribution was made in an area about one mile northwest along the coast from Nanakuli. An isolated coral mound with an area of about 50 square feet was found in a large area of sand about 150 feet from the nearest hard bottom. Associated with the mound were six live and four dead coral heads of the species Pocillopora meandrina. Five of the six heads had aggregations of juvenile fish that ranged in size from about 15 to 25 mm. in length. The five heads contained 3, 5, 12, 13, and 22 fish. A careful search of the mound failed to reveal a single fish of a predatory species. Not all of the crevices could be thoroughly explored, so the possibility exists that predators might have been present.

A nearby stretch of rock bottom was well populated by coral heads of the species Pocillopora meandrina. Small coral mounds with associated coral heads were also present in sand pockets and were as close as four to five feet from the main area of rock bottom. Thirty-eight individuals of predaceous species of fish were counted in the area within a ten minute interval. The dominant species belonged to the families Scorpaenidae and Cirrhitidae which are considered as having the greatest potential as predators of juvenile Dascyllus albisella. No juveniles were seen either on the main area of hard bottom of on the small coral mounds closely associated with the main area.

Hiatt and Strasburg (1960) also considered the problem of predation in relation to bottom living fishes in the Marshall Islands. They state that: "Hawkfish are small, solitary, demersal carnivores which lie in wait for their prey which consists mostly of crustaceans and small fish closely associated with living corals . . . The larger members of the family usually lie motionless on the top and sloping sides of living coral heads rather than partially concealed . . . " Their stomach analyses of these fishes show a high proportion of small fish including Chromis caeruleus, a small pomacentrid fish that inhabits coral heads. Randall (1955) observed a lizard fish (Synodontidae) catch a juvenile manini, Acanthurus triostegus sandvicensis, and also found them in the stomachs of moray eels. He also mentioned that squirrel fishes (Holocentridae), jacks (Carangidae), scorpaenids, hawkfishes, barracudas (Sphyraenidae) and possibly certain of the larger nocturnal crabs probably feed on manini. Although the manini is not a coral fish, it is a bottom living form as is Dascyllus albisella and is often exposed to the same kinds of predators.

3.17 DISCUSSION OF FACTORS INFLUENCING DISTRIBUTION

Examination of the various physical and biological factors in the environment of juvenile Dascyllus albisella show the complex nature of the individual components. The individual factors in the environment vary in quality and intensity, but their effect on a fish may be modified by other factors. For instance, the velocity of surge may increase or decrease which causes the distance a fish maintains between itself and its coral head to increase and decrease. However, older fish maintain a greater distance between themselves and coral heads which offsets to a certain extent the effects of the surge. The distance is also influenced by the type of bottom over which the coral head is located. Fish located over rock bottom strewn with pieces of coral, algae, etc., remain closer to their coral head than fish located over sandy bottom. In view of such considerations, it is apparent that many difficulties are involved in attempting to relate such a complex of factors. However, with the information available from this study, it is possible to create a general picture of the interaction of pertinent factors in relation to the distribution of juvenile Dascyllus albisella.

Environmental factors at Waimanalo, such as surge, bottom topography and composition, show a gradation of intensities and characteristics between the four sections studied. The differences between the extremes of the area are well-defined and form a definite basis for comparison. The area is composed of one section in which fish are concentrated in coral heads in deeper water and one section in which fewer fishes are found in shallower water. Abundance of coral heads is not a factor causing the differences in numbers of fish, since more coral heads are present in the shallow section where fish are more scarce. Certain species of predators are somewhat more abundant in the shallow section, but fluctuations in numbers of fish occur independently of their presence. Predation in the more populated deeper section also appears to be reduced both because of the absence of potential predators and because of the survival of fish associated with glomerate type coral heads which offer less protection than the ramose type that are usually colonized.

Salinity and temperature vary only slightly at Waimanalo due to the mixing action caused by surges and currents. Since these factors are rather uniform they probably have little influence on distribution of fish.

Differences in distribution of fish are unlikely to be caused by differences in distribution of food, since the same factors that result in an even distribution of temperature and salinity also result in an even distribution of plankters. The behavior of particular species of plankters as well as certain local conditions might tend to form concentrations in certain spots, but such phenomena would be difficult to evaluate. If anything, there might be a greater abundance of food in the shallow areas where fish are scarce because more water passes a given location in a given period of time. Juvenile Dascyllus albisella taken from different areas rarely have empty stomachs, which indicates that food is available most of the time.

The greatest differences were found in the velocity and frequency of surges. The shallow section was subjected to surges of considerably greater velocity than the deep section. The number of surges in a given period of time were also greater. In terms of energy expenditure, there can be little doubt that a fish living in the shallow sections must do more work to maintain a constant position in relation to a coral head. The orientation problems are relatively simple in relation to a constant current since a fish can take a position on the upcurrent side of a coral head and swim at a pace that will keep it an even distance from the head. However, the presence of surge causes the fish to almost constantly change its pace of swimming to meet the resulting increase and decrease in velocity of the water and change in direction of the surges. At one time the fish must swim hard to keep from being swept toward the coral head, and in as little time as one second or less, it may have to turn and swim hard in the opposite direction to keep from being swept away from the head. Such activity can persist for periods of time up to 30 seconds during which the fish is struggling constantly to maintain its orientation with the coral head. Isolated surges also occur frequently along with occasional cross surges, all of which require some compensating motion on the part of the fish.

By watching the behavior of fish in both sections, it became apparent that the fish in the deeper quieter section were having much less difficulty maintaining their positions in respect to the coral heads. They were not constantly being pushed toward or away from the heads by the surges before they were able to compensate, as were the fish in the shallows. Nor did they undergo interrupted periods of feeding as did fish in the shallows when they apparently could do nothing but swim hard to maintain a stationary position in the water.

It is possible that juveniles initially colonizing a coral head might leave after a period of exposure to such conditions. In this event, they would have another chance of resettling in a more favorable area. This type of behavior could represent a response to a lack or an excess of certain stimuli that result in an integration of the fish with a particular type of habitat. Under these conditions, the motivation for migrating might become dominant so that the fish would leave the shelter. This type of situation could account for the sudden disappearance of fish from urchins in which they had been living, as well as their disappearance from coral heads in turbulent areas. In the former case, the spines of the urchin could represent an inadequate visual stimulus while in the latter case, the velocity of the surges could represent an excess of a rheotactic stimulus. The high level of motivation for migrating would probably become reduced the longer a fish remained associated with a shelter such as a coral head.

The experimental coral heads placed in the two sections support the conclusion that fish tend to concentrate in calmer waters. It is significant that the numbers of fish decreased or were barely maintained on the more turbulent flats at Waimanalo while they increased in the calmer sections both there and at Waikiki where the topography of the bottom was very similar. In the latter place, the increase occurred despite the presence of many predatory fish.

Whether it is the velocity or frequency of surge that exerts the greatest influence on distribution is difficult to say, since the data at hand do not allow a comparison between these components. Both are inextricably bound together and act jointly on the fish in the field. Comparing the velocities of currents that are tolerated by fish with the velocity of individual surges is of little value since the surge is essentially a current of varying velocity. For the moment, at least, the important thing to note is that either the frequency or the velocity of the surge or both are potentially important in the early life history of this species.

The Kualua area, as at Waimanalo, shows little variation in temperature between the inshore section which is populated with fish and the turbulent surge zone section which lacks fish. The surges and currents no doubt serve to more or less completely mix the water, producing a uniform temperature. Although salinities were not determined in all locations, there is little reason to expect that they would vary to any great degree.

The predator situation appears to be quite different in the two sections. Only a few individuals of potentially predatory species were seen in the rougher section at Kualua, although numbers were greater in the calmer portions where most of the Dascyllus albisella were found. In respect to numbers, there would seem to be a greater potential for predation in the calmer section, but in total numbers of individuals as well as species of predators in the two sections, the potential is slight when compared with an area such as Waikiki. Predation undoubtedly operates in the area, but it is probably not the most important of the factors regulating distribution.

Currents in the two sections at Kualua are relatively strong and are persistent during periods when tides are flowing. Steady current, however, is probably not an important influence on the distribution of the fish since *Dascyllus albisella* are relatively abundant in the middle sections of this area. Observations made in other areas also point to a minimal role of current in influencing distribution. Juvenile *Dascyllus reticulatus*, which behave much like *Dascyllus albisella*, were found in large numbers at Eniwetok Atoll in areas where currents were as great as two knots. However, these areas were either on the lee sides of islands or were located in deep water where surge was not detected.

As at Waimanalo, the contrast in velocity of surges is very pronounced between the two sections at Kualua. The surge zone section is a very difficult one in which to work because of the high velocities of the surges. Very few fish of any kind are present although coral heads are rather abundant. Fish living in this section would be subjected to all of the problems of orientation discussed above.

It is difficult to integrate the Kaneohe Bay area into the general picture because of the uniform conditions found there, and also because there is no section where surge is pronounced to serve as a comparison. The area lies deeper underwater where surge has less effect on fish than in shallow water. Currents in the area are relatively strong, but as noted above, they are probably a relatively unimportant component of the habitat. Potential predators are practically nonexistent in the area possibly because of the lack of adequate shelter. The temperatures and salinities would be expected to vary little and are probably not a significant influence to distribution. In comparison with other areas, the Kaneohe Bay area gave the general impression of being one in which there was a moderation of the influences under discussion. The great abundance of fish no doubt results from a reduction of one or more of these factors.

The situation at Waikiki is somewhat unusual. The two sections were compared on the basis of the features dealt with in this study despite the relative lack of juvenile fish. No juveniles were ever seen in the surge section while those found in the calm section offshore were present under unusual conditions. A few were seen hiding in crevices in dead coral rocks and considerable numbers were seen temporarily associated with sea urchins.

It was recognized early in the study that the offshore section had many of the features of other areas where Dascyllus albisella were most abundant. However, ramose coral heads were almost totally absent in the section. In addition, predators were particularly numerous and were found closely associated with the two ramose coral heads that were present. A single small Pocillopora meandrina head was found growing on an anchor fluke about two feet off the bottom which effectively removed it from the predators below. Probably because of its widely separated branches and small size, numbers of fish associated with it fluctuated with the numbers of fish in sea urchins, but at least 8 juveniles of varying sizes were always associated with it.

The introduction of coral heads into the area resulted in the build-up of large numbers of associated fish. The increase in numbers of fish was noticed in heads placed on rock bottom as well as in those placed on sandy bottom, but it was much more pronounced in the latter. On the basis of these observations and experiments, it was concluded that the calm area would be a more or less optimal habitat for juveniles from the standpoint of the very slight surge found there.

As in the Kualua and Waimanalo areas, the greatest differences noted were in the velocity of surges between the two sections. The surge section had much greater average velocities than the calmer section and there was an indication that the number of surges per minute were also greater. Of all of the areas measured, the Waikiki surge section had the strongest surge and probably the greatest potential surge since the section is located outside the breaker zone where the height of the waves can become relatively great.

Temperatures and salinity differences are quite uniform throughout the area and would not be expected to have important effects on distribution.

Relatively few species of fish were seen in the surge section, including potential predators. Among those species that apparently were able to tolerate conditions in the section were the active swimmers. These species, which included mostly scarid (Labridae) and goat fishes (Mullidae), apparently were able to survive there because their swimming behavior allowed them to be swept back and forth by the surge. Fish in this area were restricted to browsing for food during periods of relative calm which reduced their energy expenditure in resisting the surge. It is probable that other species maintain themselves in the area by finding crevices or other cover that offers protection from the strong surge.

Certain species of fishes are found in "characteristic habitats" which offer sufficient protection against surge. Strasburg (1953) pointed out that the scouring and filling of tide pools by sand, which was moved around by surge, may act to keep many fish inhabitants including blennies away from such areas. As a result, most species of fish are found in more sheltered locations. Helfrich (1958) found that juvenile Abudefduf abdominalis were more abundant in tide pools that were sheltered from the direct surge by ridges, outcroppings of rock, or solution benches. It appears that juvenile Dascyllus albisella "adjust" to surge by congregating in restricted portions of the reef where surge action is relatively slight. By showing this in greater detail, this study further supplements the observations of Gosline and Brock (1960) who stated that "repeated collecting and observation of Hawaiian shore fishes over a number of years have made it increasingly clear that in shallow water, the primary factor governing zonation is wave action", which is responsible for surge.

SECTION IV

SUMMARY AND CONCLUSIONS

1. The life history, behavior and ecology of the pomacentrid reef fish *Dascyllus albisella* Gill were studied in the waters around the island of Oahu. The investigation was conducted with two goals in mind. The first was to gain more information concerning the life history and behavior including reproduction, growth and food. The second was to relate distribution to physical and biological factors in the environment including temperature, salinity, water movement and predation.

2. An analysis of the ratio of ovary weight to body weight showed that spawning occurred during the late spring and summer months. Spawning was observed only on the leeward side of the island of Oahu where the length frequency mode for adult fish was 115 mm. No spawning was observed in Kaneohe Bay, and on the basis of smaller fish captured there, it was concluded that either sexually mature fish did not enter traps or were not present in the areas sampled. The average ovary contained 25,000 spawnable eggs and size distribution of ovarian eggs indicated that spawning may take place more than once each year. Sex ratios from fish caught in both Kaneohe Bay and off Waikiki show that there were more females than males present. This

condition could have resulted from the absence of nesting male fish in the aggregations sampled.

3. Nesting occurred over a wide area off Waikiki where adult fish were common. Male fish made nests on the bottom by fanning away sediment with a vigorous swimming motion. Numbers of nests increased during the spring and summer thus corresponding with the time of maximum reproduction as shown by gonad analysis. Eggs in the field required an incubation period of 4 days at temperatures that ranged from 26.2 to 27.5 degrees C. Eggs were apparently all laid on the same day since they all hatched within one day. Comparisons between numbers of spawnable ovarian eggs and numbers of eggs in nests showed that more than one female fish may spawn in a particular nest.

4. Male fish showed a characteristic pattern of reproductive behavior around the nest. They assumed a bright white coloration and performed a series of loops in which an exaggerated anguiliform motion apparently added emphasis to the color. The male swam in front of the female and led her to the nest where the eggs were laid and fertilized. After spawning, the female left the nest and the male continued to fertilize the eggs. The male continued to drive away intruders and fanned the eggs until they hatched.

5. Dascyllus albisella larvae are described and were compared with the larvae of Abudefduf abdominalis. The former had an oval yolk sac, a line of yellow material (probably fat) along the trunk, and the pupil of the eye appeared to be colorless. The latter had a triangular yolk sac, no yellow line and the pupil of the eye appeared to be black. The gradual development of oriented movements during the first few days after hatching is described.

6. Growth rate was studied by periodically measuring the length of fish introduced into coral heads transplanted in the lagoon at the Coconut Island Marine Laboratory and at Kewalo Basin. In the former area, 8 juveniles showed an average daily growth rate of 0.17 mm. over a 14 week period. In the latter area, 4 juveniles grew an average daily rate of 0.14 mm. over a 35 day period. Observations on feeding behavior indicate that growth rate might vary with the location of the fish. In lagoons and other areas with relatively little current, fish fed at a slow pace, whereas in areas of current and surge, feeding activity was greatly accelerated. It was apparent that the planktonic organisms on which fish fed were more plentiful in the latter areas, probably because of the increased flow of water that brought more food past the fish.

7. An analysis of the weight of various kinds of organisms in stomachs showed that the most abundant

plankters were copepods, larvaceans, shrimp-like crustaceans and fragments of polychaet worms. Adult fish in Kaneohe Bay fed close to the bottom, whereas adults off Waikiki fed up to 50 feet above the bottom. Juveniles fed close to the coral head and occasionally darted beyond their normal range after food. Stomachs of fish were seldom empty and indicated that food was plentiful.

8. Attempts to study migration by tagging fish were largely unsuccessful. However, a total of 38 adult fish were tagged off Waikiki and subsequent observations over a 3 month period indicated that movement was slight between 2 aggregations separated by a distance of 70 yards. Observations also showed that some tagged fish remained together in small groups without dispersing individually throughout the aggregation. A number of tagged fish showed abnormal behavior by remaining among coral on the bottom for about a week after receiving the tag.

9. Three kinds of coloration were recognized and they appeared to be correlated with the state of activity of the fish. Male fish in nuptial coloration were white except for a black caudal and anal fin and a black distal edge on the dorsal fin. Nuptial coloration was almost identical to feeding coloration except that the former appeared to be brighter due to the lack of pigmentation on the edges of the scales. Although fish displaying nuptial coloration

were in a state of reproductive activity, they were not continually active. This may account for their similarity in color to slow-moving fish in feeding aggregations. In contrast to the above, some fish were dark gray or black with a light area in the middle of the body. Such fish were usually in a relatively high state of activity and the related color was termed excitation coloration. The darker or lighter coloration developed within a few minutes, and changed with the activity of the fish.

10. Ecology of juveniles was studied by observing concentrations of fish in relation to various environmental factors. Studies were carried out on reefs near Waimanalo, Kualua, in Kaneohe Bay and off Waikiki. Most fish were concentrated in the inner portions of reefs away from the surge zone. However, it was apparent that all gradations existed within the reef from surge conditions to calm water. Periodic counts of numbers of fish in coral heads at Waimanalo were used as a basis for comparison with the different environmental conditions encountered. In that area, fish were less abundant on shallow flats, but were more numerous in the deeper channels. Comparisons between the other study areas also showed that fish were relatively scarce on shallow flats, but were more abundant in deeper channels and other depressions.

11. Some relationships between juveniles and coral

heads were studied. An analysis of length frequency distributions showed that fish entered coral heads when they were about 15 mm. in length. An aggregation of fish showed a characteristic behavior toward its coral head. In moving water, the fish remained together on the upcurrent side of the head where they fed actively on plankters that drifted past. In calm water the aggregation became umbrella-shaped around the coral head. In this formation, the individuals became widely spaced and also moved somewhat farther from the head. The aggregations had a definite organization in which the larger fish remained farther from the head, and the smaller fish remained closer. As fish grew larger, the distance they maintained between themselves and the head increased until they became independent of the head. Stomach analyses showed that large fish "screened out" certain planktonic organisms that probably would have been eaten by smaller fish in the absence of the larger fish.

12. A number of hydrographic features of the environment were compared between the areas. The similarity of temperatures and salinities in areas where fish were relatively scarce as well as in areas where fish were comparatively abundant indicated that these factors were probably not major determinants of distribution. Comparable numbers of fish in areas where current was strong as well as in areas where current was weak, indicated that this factor

was of little importance. However, measurements of the velocity and frequency of surges showed a wide variation between different areas. Both velocities and frequencies were relatively strong in shallow areas where fish were least abundant and both factors were relatively weak in deeper water where fish were most abundant. The effects of surge on the orientation of fish to coral heads were discussed along with the broader aspects of the way in which surge and other factors might affect distribution.

13. Although Dascyllus albisella were not found in stomachs of predatory species of fish, a number of potential predators were observed. Certain behavioral traits of fishes of the families Scorpaenidae, Aulostomidae, and Fistulariidae indicated that they might prey on Dascyllus albisella.

14. Field experiments were conducted in which juvenile fish were introduced into transplanted coral heads off Waikiki and Waimanalo. Large aggregations of fish accumulated in the coral heads in the deep waters off Waikiki and in the deep channel at Waimanalo. However, no build-up in numbers occurred in the shallow flats in the latter area where surge was strong. This build-up in numbers of fish in relatively surge-free areas was interpreted as further evidence that fish were not able to remain in places where surge was strong. The large numbers of fish that

accumulated in transplanted coral heads at Waikiki showed that the absence of naturally occurring coral heads was one reason why few juveniles were found there.

15. Associations between juveniles and sea urchins were observed on three occasions off Waikiki. In view of the fact that numbers of fish associated with urchins fluctuated from zero to over 80 fish, it was apparent that urchins were a temporary habitat. Fish associated with urchins were very shy and mostly remained between the spines.

16. In Kaneohe Bay, juveniles were sometimes observed among the tentacles of the sea anemone _Marcanthia cookei_. Aquarium observations showed that fish gradually became acclimated to the anemones by repeatedly touching the tentacles with the caudal fin. The fish were eventually able to lie motionless among the tentacles and to swim freely among them. In the presence of the anemone, the fish undergo a more or less set pattern of behavior similar to that of true anemone fishes (_Amphiprion_). The evolution of commensal associations between pomacentrid fishes and anemones is discussed.

BIBLIOGRAPHY

Abel, E.F. von, 1960. Zur Kenntnis des Verhaltens und der Ökologie von Fischen an Korallenriffen bei Ghardaqa (Rotes Meer). Zeit. Morph. Okol. Tiere 49: 430-503.

__________ 1961. Freiwasserstudien über das Fortpflanzungsverhalten des Monchfisches *Chromis chromis* Linnè. einem Vertreter der Pomacentriden im Mittelmeer. Zeit. Tierpsychol. 18(4): 441-449.

Andrewartha, H.G. 1961. *Introduction to the study of animal populations.* Univ. Chicago Press: 281 pp.

Baerends, G.P. 1950. Specializations in organs and movements with a releasing function. Symp. Soc. Exp. Biol. 4: 337-360.

Baerends, G.P. and J.M. Baerends-van Roon. 1950. *An introduction to the study of the ethology of cichlid fishes.* Behavior. E.J. Brill, Leiden. Suppl. 1: 1-243.

Bardach, J.E. 1958. On the movements of certain Bermuda reef fishes. Ecology 39(1): 139-146.

Bigelow, H.B. 1926. Plankton of the offshore waters of the Gulf of Maine. Bull. U.S. Bur. Fish. 40(2): 97-106.

Bigelow, H.B. and W.W. Welsh. 1925. Fishes of the Gulf of Maine. Bull. U.S. Bur. Fish. 40(1): 99-105.

Breder, C.M., Jr. 1932. Breeding of the beau gregory. Bull. N.Y. Zool. Soc. 35(4): 120-121.

__________ 1948. Observations on coloration in reference to behavior in tide-pool and other marine shore fishes. Bull. Amer. Mus. Nat. Hist. 92(5): 281-312.

__________ 1949. On the relationship of social behavior to pigmentation in tropical shore fishes. Bull. Amer. Mus. Nat. Hist. 94(2): 83-106.

__________ 1950. Factors influencing the establishment of residence in shells by tropical shore fishes. Zoologica 35(12): 153-158.

__________ 1959. Studies on social groupings in fishes. Bull. Amer. Mus. Nat. Hist. 117(6): 397-481.

Breder, C.M., Jr. and C. W. Coates. 1933. Reproduction and eggs of _Pomacentrus_ _leucoris_ Gilbert. Amer. Mus. Novit. 612: 1-6.

Breder, C.M., Jr. and P. Rasquin. 1955. Further notes on the pigmentary behavior of _Chaetodipterus_ in reference to background and water transparency. Zoologica 40(7): 85-90.

Brian, M.V. 1952. The structure of a dense natural ant population. Jour. Anim. Ecol. 21: 12-24.

Brinley, F.J. 1939. Spawning habits and development of beau-gregory (Pomacentrus leucostictus). Copeia (4): 185-188.

Clarke, G.L. 1954. Elements of ecology. John Wiley and Sons, Inc.: 534 pp.

Collingwood, C. 1868. Note on the existence of gigantic sea anemones in the China sea, containing within them quasiparasitic fish. Ann. Mag. Nat. Hist. 4(1): 31-32.

Cott, H.B. 1940. Adaptive coloration in animals. Methuen and Co., London: 508 pp.

Crespigny, C.C., de, 1869. Notes on the friendship existing between the malacopterygian fish Premnas biaculeatus and the Actinia crassicornis. Proc. Zool. Soc., London: 248-249.

Davenport, D. and K.S. Norris. 1958. Observations on the symbiosis of the sea anemone Stoichactis and the pomacentrid fish, Amphiprion percula. Biol. Bull. 115(3): 397-410.

De Bach, P. 1949. Population studies of the long-tailed mealybug and its natural enemies on citrus trees in southern California. Ecology 30: 14-25.

Eibl-Eibesfeldt, I. 1960. Beobachtungen und Versuche an Anemonefischen (*Amphiprion*) der Maldiven und der Nicobaren. Zeit. Tierpsychol. 17(1): 1-10.

Elten, C.S. 1949. Population interspersion: an essay on animal community patterns. Jour. Ecol. 37: 1-25.

Franzisket, L. 1959. Experimentelle Untersuchung über die optische Wirkung der Streifung beim Preussenfisch (*Dascyllus aruanus*). Behavior 15(1,2): 77-81.

Garnaud, J. 1951. Nouvelles données sur l'ethologie d'un Pomacentridae: *Amphiprion percula* Lacépède. Bull. Inst. Océanogr. Monaco 998: 1-12.

__________ 1957. Ethologie de *Dascyllus trimaculatus* (Rüppell). Bull. Inst. Océanogr. Monaco 1096: 1-10.

Gohar, H.A.F. 1934. Partnership between fish and anemone. Nature 134(3382): 291.

__________ 1948. Commensalism between fish and anemone (with a description of the eggs of *Amphiprion bicinctus* Rüppell). Publ. Mar. Biol. Sta., Ghardaqa (Red Sea) 6: 35-44.

Gosline, W.A. and V.E. Brock. 1960. *Handbook of Hawaiian fishes*. Univ. Hawaii Press, Honolulu: 372 pp.

Gudger, E.W. 1929. On the morphology, coloration, and behavior of seventy teleostean fishes of Tortugas, Florida. Carnegie Inst. Washington. Publ. 391: 149-204.

__________ 1947. Pomacentrid fishes symbiotic with giant sea anemones in Indo-Pacific waters. Jour. Asiatic Soc. Beng. 12: 53-76.

Harry, R. 1953. Ichthyological field data of Raroia Atoll Tuamotu Archipelago. Atoll Res. Bull. 18: 190 pp.

Helfrich, P. MS. The early life history and reproductive behavior of the maomao, _Abudefduf abdominalis_ (Quoy and Gaimard). _Univ. Hawaii, Doctor of Philosophy Thesis_, August 1958.

Herre, A.W.C.T. 1936. Some habits of _Amphiprion_ in relation to sea anemones. Copeia (3): 167-168.

Hiatt, R.W. and D.W. Strasburg. 1960. Ecological relationships of the fish fauna on coral reefs of the Marshall Islands. Ecol. Monogr. 30: 65-127.

Hildebrand, S.F. and W.C. Schroeder. 1927. Fishes of the Chesapeake Bay. Bull. U.S. Bur. Fish. 43(1): 89-100, 102-105.

Hoar, W.S. 1957. Endocrine organs. In: _The physiology of fishes_, M.E. Brown, Edit. Academic Press, Inc., N.Y. Vol. 1: 447 pp.

Lebour, M.V. 1919. The food of post-larval fish. 2. Jour. Mar. Biol. Assoc., U.K. 12(1): 22-47.

Limbaugh, C. MS. Life history notes on the two California representatives of the demoiselle family, Pomacentridae: The garibaldi Hypsypops rubicunda (Girard) and the blacksmith Chromis punctipinnis (Cooper).

Longley, W.H. and S.F. Hildebrand. 1941. Systematic catalogue of the fishes of Tortugas, Florida. Tortugas Lab., Papers 5 (Carnegie Inst. Washington Publ. 535): 331 pp.

Macfadyen, A. 1957. Animal ecology: aims and methods. Sir Isaac Pitman and Sons, Ltd., London: 264 pp.

Mast, S.O. 1916. Changes in shade, color, and pattern in fishes and their bearing on the problem of adaptation and behavior, with especial reference to the flounders Paralichthys and Ancylopsetta. Bull. U.S. Bur. Fish. 34: 173-238.

Noble, G.K. 1938. Sexual selection among fishes. Biol. Rev. 13: 133-158.

Odum, H.T. and E.P. Odum. 1955. Trophic structure and productivity of a windward coral reef communtiy on Eniwetok Atoll. Ecol. Monogr. 25: 291-320.

Parker, G.H. 1948. *Animal colour changes and their neurohumors.* Cambridge Univ. Press: 377 pp.

Pelkwijk, J.J. ter and N. Tinbergen. 1937. Eine reizbiologische Analyse einiger Verhaltensweisen von *Gasterosteus aculeatus* Linnè. Zeit. Tierpsychol. 1: 193-204.

Randall, J.E., Jr. MS. A contribution to the biology of the Acanthuridae (surgeon fishes). *Univ. Hawaii, Doctor of Philosophy Thesis*, June 1955.

__________ 1960. Examples of mimicry and protective resemblance in tropical marine fishes. Bull. Mar. Sci. Gulf and Carib. 10(4): 444-480.

Shaw, E.S. 1955. The embryology of the sergeant major, *Abudefduf saxatilis* (Linnè.). Copeia (2): 85-89.

Shelbourne, J.E. 1953. The feeding habits of plaice post-larvae in the southern bight. Jour. Mar. Biol. Assoc., U.K. 32(1): 149-159.

Sluiter, C.P. 1888. Ein mergwurdiger Fall von Mutualismus. Zool. Anz. 11: 240-243.

Smith, J.L.B. 1960. Coral fishes of the family Pomacentridae. Rhodes Univ., Grahamstown, South Africa. Ichthyol. Bull. 19: 317-349.

Strasburg, D.W. MS. The comparative ecology of two salarin blennies. Univ. Hawaii, Doctor of Philosophy Thesis, June 1953.

Tester, A.L. 1951. Methods of fisheries research. (Mimeo.). Univ. Hawaii, Honolulu: 77-81.

Tester, A.L. and M. Takata. 1953. Contributions to the biology of the aholehole, a potential baitfish. Industrial Res. Advisory Coun. Grant No. 29. Final Rep.: 1-54.

Tinbergen, N. 1951. The study of instinct. Clarendon Press, Oxford: 228 pp.

Verwey, J. 1930. Coral reef studies. 1. The symbiosis between damsel fishes and sea anemones in Batavia Bay. Treubia 12(3-4): 305-354.

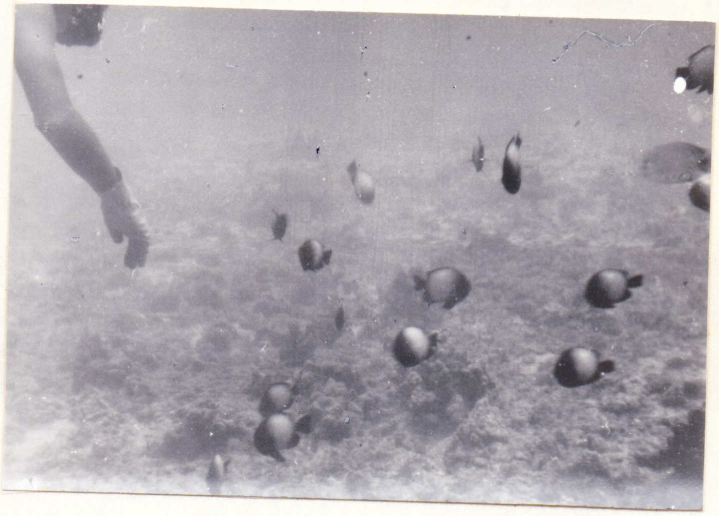

Figure 14. Adult Dascyllus albisella showing excitation colors in response to the activity of the diver.

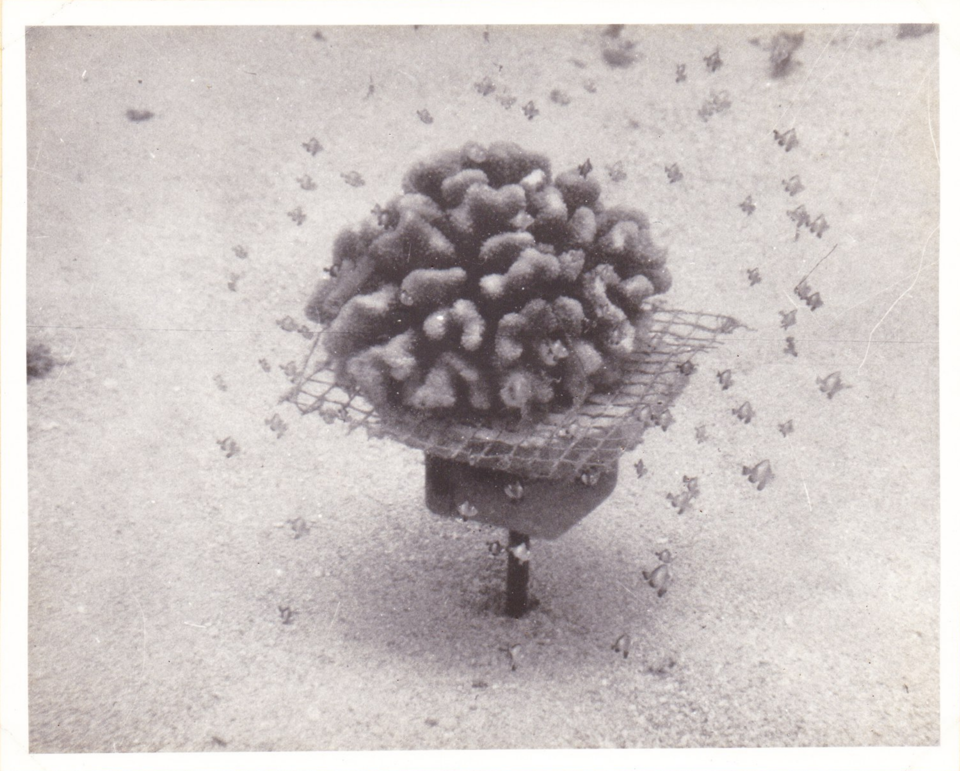

Figure 21
Juvenile *Dascyllus albisella* associated with experimental coral head # 1 off Waikiki.

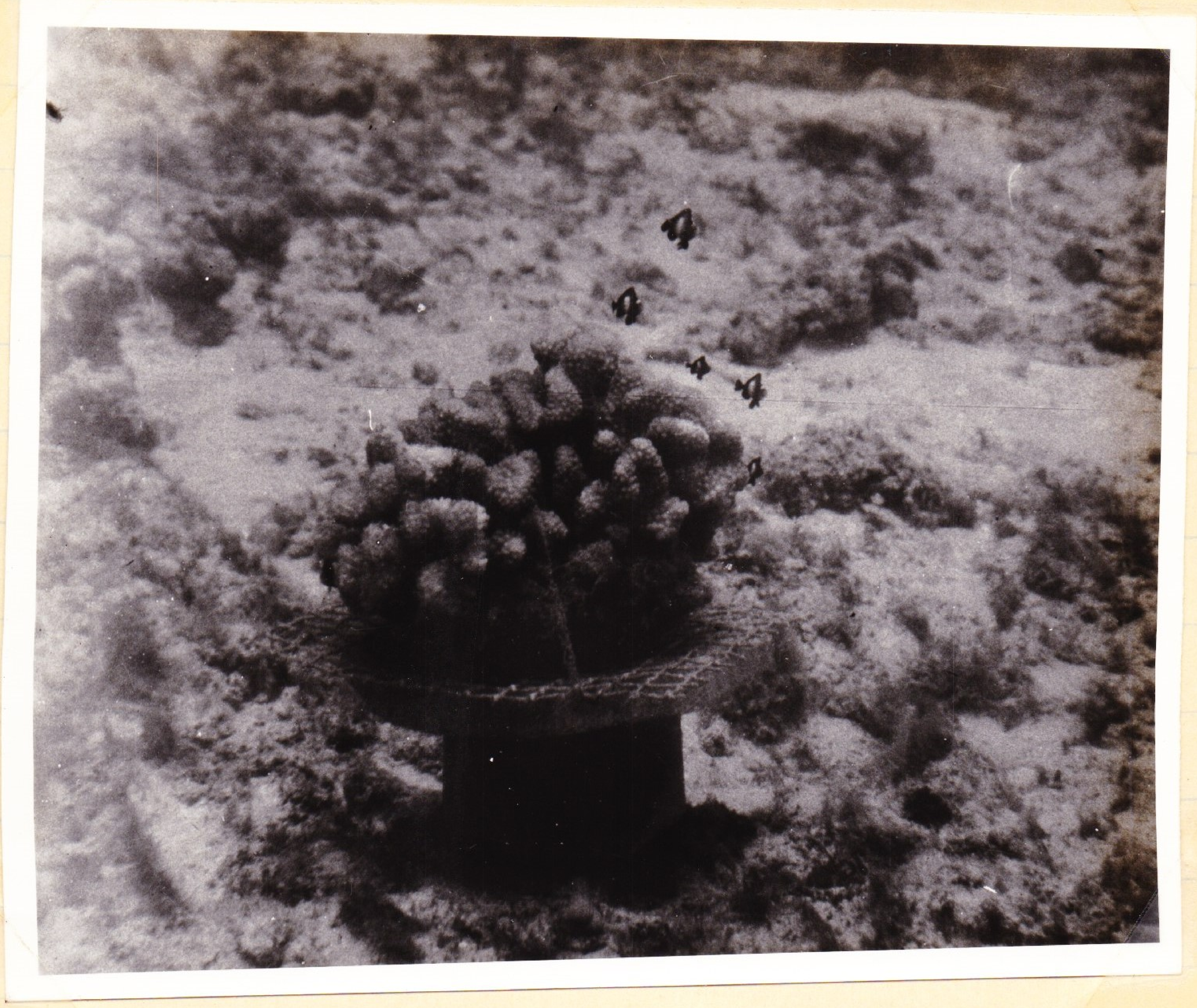

Figure 20

Juvenile *Dascyllus albisella* associated with experimental coral head # 9 off Waikiki.

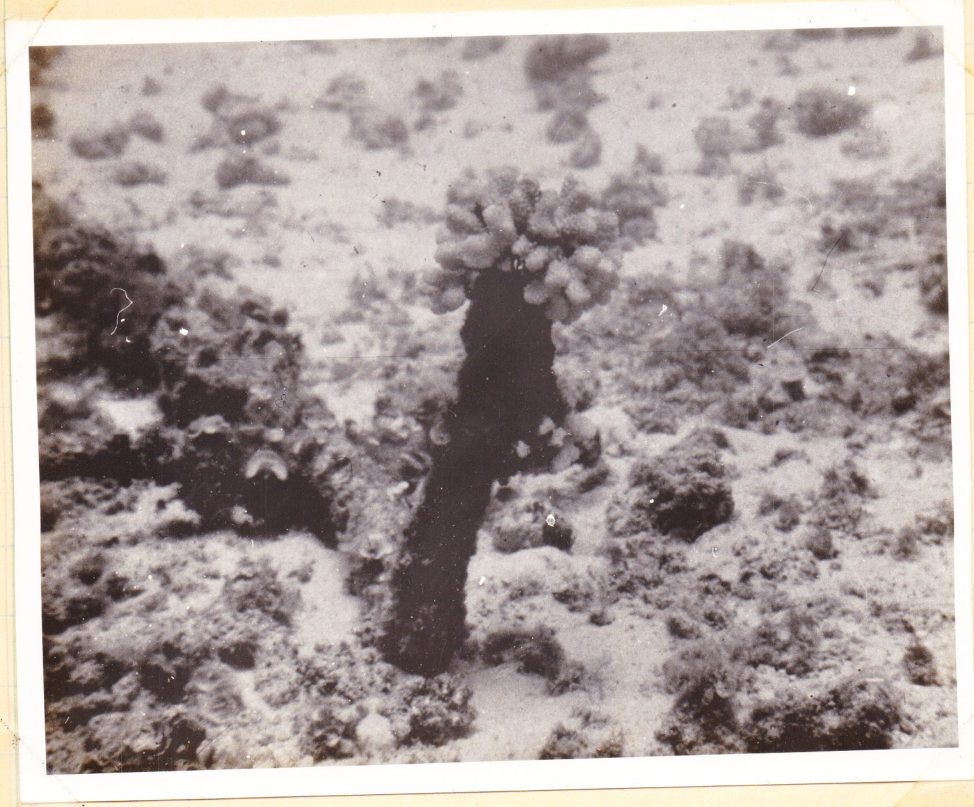

Fig 7

after p. 13